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POPULATION TRENDS OF THE ALFALFA WEEVIL (COLEOPTERA: CURCULIONIDAE) AND ITS ASSOCIATED PARASITES IN MARYLAND AND NEW JERSEY, 1966–1970

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Abstract.—Populations of the alfalfa weevil, *Hypera postica* (Gyllenhal), in Maryland and New Jersey and of associated parasites changed greatly in the period 1966–70. The alfalfa weevil declined rapidly during the period under the increasing pressures of the introduced parasites *Bathyplectes curculionis* (Thomson), *Tetrastichus incertus* (Ratzeburg), *Microctonus colesi* Drea, *Microctonus aethiopoides* Loan and *Bathyplectes anurus* (Thomson).

The biology and ecology of the alfalfa weevil, *Hypera postica* (Gyllenhal), and of the associated parasites in Maryland and New Jersey were reported for the period 1961 to 1967 by Blickenstaff et al. (1972). This study included details concerning the life history, habits, and movement of the weevil, the importance of fall-laid eggs, the number of generations/year, the levels of populations, the establishment, spread and percent parasitism of introduced parasites, and the results of surveys of fall and winter populations of adults done so investigators could predict larval populations and damage. Much other work done on the biology and life history of the alfalfa weevil was listed by Cothran (1966).

The population surveys of the alfalfa weevil begun by Blickenstaff and Huggans (Blickenstaff et al. 1972) in 10 fields in Maryland and New Jersey in 1964 and 1965 were continued and are reported here for the period from fall 1966 to spring 1970. The fields in Maryland and New Jersey that were surveyed from fall 1966 through March 1968 were the same as fields surveyed by Blickenstaff et al. (1972). Thus, Maryland fields 1 and 2 were in Howard County, near Clarksville; fields 3, 4, 5, and 6 were at Beltsville, Prince George's County; field 7 was in Howard County near Jessup; fields 8 and 9 were at Crownsville, Anne Arundel County; and field 10 was in Montgomery County near Rockville. In New Jersey, the survey fields established by Blickenstaff in cooperation with the New Jersey Department of Agriculture were: fields 1 and 2 in Sussex and Warren Counties in the upper Appalachian Valley; field 3 in Warren County in the Lower Appalachian Highlands; fields 4 and 5 in Hunterdon and Mercer Counties in the Lower Appalachian Piedmont area; and fields 6–10 in Monmouth, Burlington, Gloucester, and Cumberland Counties in the Inner Coastal Plain area. The single major change in field locations was made in March 1968 when 8 out of the 10 Maryland fields were dropped and 8 new fields were chosen.

This change was made to provide a more complete evaluation of weevil populations in the major alfalfa producing areas of central and western Maryland. Two of the original 10 fields (field 9 at Clarksville and field 10 at Beltsville) were retained for comparison. The new locations were: fields 1 and 2 at Goshen and Boyds, Montgomery County; fields 3 and 6 at Frederick and Thurmont, Frederick County; fields 4 and 5 at Boonesboro and Smithburg, Washington County; and fields 7 and 8 at Westminster and Sykesville, Carroll County.

To maintain uniformity in sampling and analysis of the data collected, we determined populations of larvae from April through July by examining plant material (foliage) from 1- or ½-ft² samples or removed adults from ground samples during the winter season with a suction device. However, in March 1968 the number of samples (½ ft²) for adult alfalfa weevil collections was increased from 10 to 20 per field. The sampling of insects in the field and the processing of samples in the laboratory were generally the same as those reported by Blickenstaff et al. (1972), and where modifications were introduced, they are noted.

Until 1968, adult alfalfa weevils were collected October through March from each field with a D-Vac suction machine designed and developed by Dietrick (1961). However, when more extensive field surveys were undertaken in 1968, the machine was mounted on wheels to reduce the time, labor and fatigue involved in sampling (Schroder 1970). The adults that were collected with the vacuum were separated from debris by sieving and then collected by forceps and counted.

Collections of larvae were made by cutting ten ½-ft² foliage samples at ground level and placing the foliage with the insects in paper bags. The samples from the 10 New Jersey alfalfa fields were collected by personnel of the New Jersey Department of Agriculture and then processed at Beltsville, Maryland. The samples from the 10 Maryland alfalfa fields were collected by personnel of USDA and processed at Beltsville. A maximum of 50 3rd–4th instar larvae were removed from each of the foliage samples and placed with a fresh bouquet of alfalfa in a container. The container consisted of a 6 in. glass tube (2″ diam.) sealed at one end with parachute cloth and a cork with a vial inserted in the center at the other end. The alfalfa was placed in the vial and sealed with a sponge. This provided a cage for the larvae to develop to adults. The cages were checked daily for the emergence of parasites from the larvae. Additional collections of larvae were made by sweeping the alfalfa at times when low numbers of larvae were present. Foliage samples were then processed by using a high-speed blender-water extraction technique (Schroder 1974) instead of the alcohol-kerosene method of Blickenstaff and Huggans (1969). By the new procedure, the 1st to 4th instar larvae were dislodged from the alfalfa in a high speed blender and then separated from the debris by washing through a series of sieves. The

number of larvae/½ ft² was then determined by totaling the number obtained for recovery of parasites and the number recovered by extraction. Then the number of larvae/ft² for each field could be calculated and recorded.

Microctonus colesi Drea (Braconidae) and *M. aethiopoides* Loan (Braconidae), parasites of adult alfalfa weevils, are difficult to recover because of the diapause of the host and the diapause of the parasite larvae in the host. Neal et al. (1971) demonstrated that topical application of the juvenile hormone cis-trans and trans-trans 10,11 epoxyfarnesenic acid methyl ester brought forth larvae of both *Microctonus* parasites. Once the parasite larvae emerge from the host and if adult *Microctonus* did not emerge, species identification was a problem. There were no dependable external body characters available for use in distinguishing the larvae of these parasites until Fuester (1970) separated them by the size of their mandibles.

There were three methods used to determine parasitism of adults: 1) hold the weevil adults on fresh bouquets of alfalfa in small cages until the parasites emerge, 2) dissect adults, and 3) treat with synthetic juvenile hormone. Depending on the availability of the hormone, it was applied topically on the venter of the abdomen with 100 μg of the hormone in 0.5 μliter acetone with a microinjector. The weevils were then held for emergence of parasites for 30 days and then dissected to determine presence of parasite larvae.

Alfalfa Weevil Adult Populations

1966–1967

Surveys for alfalfa weevil adults begun in September 1966 in Beltsville, Maryland signaled that the adults did not start to return to alfalfa fields until early October and reached a peak, a high of 6.7 adults/ft², in mid-November (Table 1). Numbers then declined by 67% to 2.3/ft² in mid-March 1967. A similar decline was apparent in New Jersey fields, although only 2 collections were made. The fewer collections made in New Jersey make it difficult to pinpoint the peak population for this area as accurately as for Maryland, but we feel that the figures in Table 1 provide a valid estimate of the levels. Thus, populations in New Jersey were approximately ½ those in Maryland, but the declines (63%) from mid-November to mid-March were very similar. The same approximate 2 to 1 difference in adult numbers in Maryland vs. New Jersey and the ⅔ decline in adults was reported by Blickenstaff et al. (1972) for the winters of 1964–66.

1967–1968

Regular collections were put off until October 30, 1967, in Maryland because earlier collections in Beltsville were not successful. The totals showed fewer alfalfa weevils than in 1966 and a later return of the adults to the fields

Table 1. Alfalfa weevil adults/ft² in 10 Maryland and 10 New Jersey survey fields. 1966–1970[1].

Date	1966–1967 Maryland	1966–1967 New Jersey
9/23	.02	—
10/20	2.86	—
11/14	6.66	—
11/17	—	3.54
12/12	4.74	—
1/17	2.92	—
2/27	1.30	—
3/16	2.26	—
4/4	—	1.32
	1967–1968[2]	
10/30	1.24	—
11/21	—	1.36
11/20	1.68	—
12/19	2.26	—
3/25	1.63	—
3/27	—	.88
	1968–1969	
11/22	.51	—
12/20	.29	—
1/16	—	.18
1/27	.16	—
2/19	.15	—
3/11	.14	—
4/8	—	.26
4/11	.76	—
4/19	.45	—
4/24	.41	—
	1969–1970	
10/14	.43	—
10/22	.51	—
10/30	.51	—
11/24	.96	—
12/3	.48	—
12/11	.77	—
2/27/70	.11	—
3/10	.23	—
3/26	.21	1.4
4/29	.66	—

[1] Average for 10 fields, 10 ½ ft² samples/fields. — = no samples taken that date.

[2] Sample size for adult collections was increased from 10 to 20 ½ ft² samples/field. Change effective from 3/25/68–4/29/70.

(Table 1). Populations peaked at 2.3/ft² in mid-December and declined to 1.6/ft² by late March, a reduction of only 30%. In New Jersey, populations were again about ½ those in Maryland and the overwinter reduction was 35%. This was the first year since the surveys were begun in 1964 that the decline in numbers of adults from fall to spring was less than 60%. This sharp reduction in measurable overwintering mortality plus the late return of adults in the fall of 1967 suggests that fewer adults returned to the fields in the fall, but that larger numbers than normal returned in the spring. Such spring migrations of adults had not previously been considered important in the Maryland–New Jersey area, but are a common occurrence in New York (Poinar and Gyrisco 1962).

1968–1969

Collections of adults in both states in the fall of 1968 showed greatly reduced populations and much later appearance of adults, confirmation of the trend reported for 1967 (Table 1). As in 1967, this late return was signaled by failure to collect them in numerous alfalfa fields in the Beltsville area. For this reason, regular collections were not begun until November. Although populations were low throughout the 1968–69 season, numbers of adults were actually higher in the spring of 1969 than the previous fall, another indication of change in the migration of the weevil. The trend was obvious in both states though populations remained lower in New Jersey than in Maryland.

1969–1970

D-Vac sampling was begun October 14, 1969, when the first adults were recovered by sweeping. Once again, populations in Maryland were relatively low (Table 1), and the decline in overwintering Maryland adults was lower than in the 1966–67 season. In New Jersey, sampling was not done during the fall season; however, the samples taken in March 1970 showed an average 1.4 adults/ft², an increase over the average for the spring of 1968 and 1969.

Alfalfa Weevil Larval Populations

The mean numbers of alfalfa weevil larvae/ft² for the 10 Maryland and 10 New Jersey alfalfa fields (calculated from the combined means of the larvae/ft² in individual fields) are shown in Figures 1 and 2. In 1967, larval populations peaked earlier than anticipated in both states and reached the highest levels seen since the surveys were begun in 1964, 370 and 265 for Maryland and New Jersey, respectively (Figs. 1 and 2). Populations in both states remained above the 100 larvae/ft² level for over 6 weeks. The New Jersey peak occurred approximately 3 weeks later than the Maryland peak.

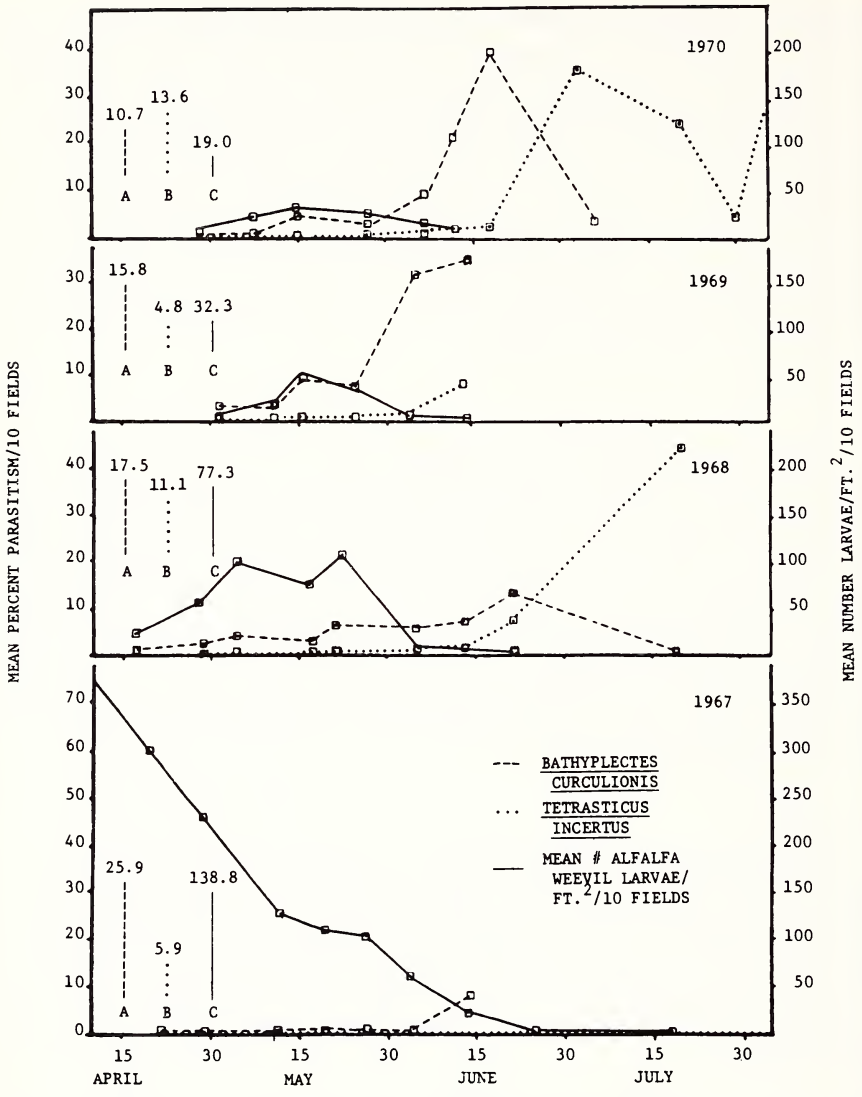

Fig. 1. Maryland: Mean number alfalfa weevil larvae/ft² per 10 fields (——) and mean percent parasitism of the larvae by *B. curculionis* (- - -) and *T. incertus* (. . .), 1967–70. The figures A B C represent the pooled standard deviations of the means.

In 1968 the larval buildup peaked almost one month later than in previous years in Maryland and 2 weeks later in New Jersey. In addition, the average number (over 10 fields) for both states was 75% of that for 1967 (100% in Maryland and 65% in New Jersey). In Maryland, populations remained at

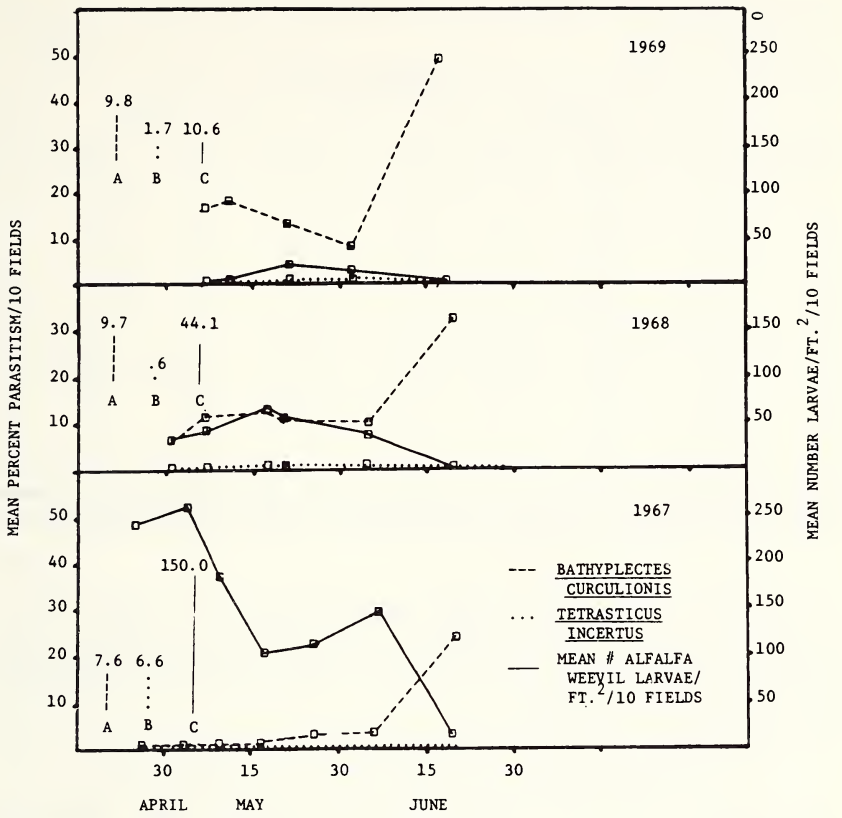

Fig. 2. New Jersey: Mean number alfalfa weevil larvae/ft² per 10 fields (——) and mean percent parasitism of the larvae by *B. curculionis* (- - -) and *T. incertus* (. . .), 1967–69. The figures A B C represent the pooled standard deviations of the means.

the peak level for about 2 weeks, which created a plateau rather than a sharp peak as in previous years (Figs. 1 and 2).

Alfalfa weevil larval populations in 1969 were lower in both states than in 1968. The peak in Maryland occurred about 1 week later than in 1968; the peak in New Jersey occurred about 1 week later than in Maryland. A comparison of the mean peak larval populations of the 10 fields in both states from 1967 to 1970 showed a 86 and 92% reduction in numbers of larvae/ft² in Maryland and New Jersey, respectively (Table 2).

In 1970 the larval populations declined to the lowest level since the surveys were begun (Figs. 1 and 2).

Thus, since 1967, the number of larvae collected in field 10 in Maryland, one of the two fields sampled all 4 years, has declined from a peak of 980

Table 2. Peak number of alfalfa weevil larvae for each of the 10 fields in Maryland and New Jersey, 1967–1970.

Field no.	Peak number larvae/ft²							
	New Jersey				Maryland			
	1967	1968	1969	1970	1967	1968[1]	1969	1970
1	157	62	21	45	316	41	77	27
2	168	76	18	10	531	231	46	71
3	133	27	35	35	557	45	39	12
4	401	93	21	18	585	129	140	38
5	351	45	30	9	544	334	161	58
6	194	55	15	17	147	97	61	28
7	124	103	12	7	541	65	14	63
8	532	211	32	16	169	96	49	31
9	813	216	7	17	320	84	42	26
10	593	67	81	20	980	86	49	29
x	346.6	95.5	27.2	19.4	469.0	120.8	67.8	38.3

[1] Fields 2 and 10 in Maryland sampled again in 1969; all others in 1969 were new locations.

to 29 larvae/ft². The overall decline was 92% for all 10 fields (Table 2). Nevertheless, there were some areas that had severe larval damage. In New Jersey, larval populations also declined by 92% and so have remained at about ½ the Maryland levels.

Correlations Between Adult and Larval Populations

Blickenstaff et al. (1972) indicated that correlation of adult alfalfa weevil populations collected in November and March with the peaks of larval populations that followed were helpful in predicting potential damage to alfalfa. It was one of the objectives of continuing the two-state surveys to predict potential damage from such correlations. The relationship between these adult numbers and the peak larval populations in individual fields is shown in Table 3. Significant correlations were obtained for Maryland fields in 1966–67 except for adults collected in February. Also, significant correlations were obtained for New Jersey fields for November 1966 and March 1968. Likewise, in 1968–69, significant correlations were obtained between Maryland adults collected in January and March and peak spring larval numbers and between New Jersey adults collected during April 1969 and the peak in spring larvae. Correlations were not obtained between Maryland adults collected in 1969 or 1970, and the 1970 peak larval populations and correlations were not available for the 1969–70 season in New Jersey because samples were not collected. The change in behavior of the overwintering adults in Maryland identified from the sampling is evident in the lack of the uniform correlation between adults and peak larval populations dem-

Table 3. Correlations between winter collected adult alfalfa weevil populations and peak larval populations the following spring.

Adults collected	1966–67		1967–68		1968–69		1969–70
	Md.	N.J.	Md.	N.J.	Md.	N.J.	Md.
Oct.							.19
Nov.	.85**[1]	.73*	.35	.05	.57		.21
Dec.	.73*		.18				.14
Jan.	.66*				.72*		
Feb.	.59						.32
March	.76**	.52	.37	.67*	.98**		.31
April					.51	.88**	.20

[1] ** Indicates significance at 1%. * Indicates significance at 5%.

onstrated by Blickenstaff et al. (1972). However, the significance of the correlations (Table 3), despite this change, support the idea that the number of overwintering adults can be helpful in predicting potential larval populations.

Parasites of the Alfalfa Weevil

The history of releases and recoveries of the alfalfa weevil parasites in Maryland and New Jersey was reviewed by Blickenstaff et al. (1972) and Dysart and Day (1976). It was the main objective of the continuing surveys to determine the incidence of and percent parasitism by alfalfa weevil parasites in the 10 alfalfa fields of Maryland and New Jersey.

Larval Parasites

As indicated, the alfalfa foliage in ½ ft^2 at 10 or 20 sites in each field on each sampling date was shaken to dislodge larvae and those in the 3rd and 4th stadia were held for parasite recovery. The supplemental surveys were processed in the same manner so we would have additional larvae, if necessary, to observe for parasite recovery. A maximum of 50 such larvae from each sample were placed in containers with fresh alfalfa and reared to adults in the laboratory at room temperature. The containers were examined weekly for emerging parasites.

Bathyplectes curculionis (Thomson) (Ichneumonidae), an introduced larval parasite, was the predominant parasite of the alfalfa weevil collected in the 10 Maryland and 10 New Jersey alfalfa fields from 1967 to 1970. In Maryland, the highest level of parasitism for a single field was 64% on June 20, 1968, in New Jersey, the highest level recorded was 61% on June 19, 1968. The increased synchronization between populations of *B. curculionis* and the peak population of alfalfa weevil larvae in Maryland and New Jersey

through the 1969 season that is shown on Figures 1 and 2 suggests an increased effectiveness of the parasite, especially in New Jersey. The mean percent parasitism of alfalfa weevil larvae by *B. curculionis* shown in these figures was calculated by using the means for percentage parasitism for the individual fields.

Bathyplectes anurus (Thomson) is another introduced larval parasite. It was recovered in 1970, for the first time in these surveys, in New Jersey. There it was parasitizing 30% of the larvae collected in field 7. The parasite was not recovered from larvae collected in any of the 10 Maryland alfalfa fields during the time of these surveys. This is not surprising since the first record for recovery of *B. anurus* in Maryland was in Prince George's County in 1972. The first record for recovery in New Jersey was in Monmouth County in 1967 (Dysart and Day 1976).

Tetrastichus incertus (Ratzeburg) (Eulophidae) is an introduced larval parasite that becomes abundant in Maryland and New Jersey alfalfa in late summer, generally after the first cutting when host density is low; it therefore appears later than the *Bathyplectes* species. This parasite has been established in Maryland since 1964; its spread and distribution in the eastern United States, especially in Maryland and New Jersey, was reported by Schroder et al. (1969). The incidence and mean percent parasitism of the alfalfa weevil by *T. incertus* in the 10 Maryland and 10 New Jersey alfalfa fields for the period 1967–70 was calculated by using the means for percentage parasitism for the individual fields and is shown in Figures 1 and 2. Plainly *T. incertus* parasitism increased very rapidly in the Maryland survey fields: it was 14% in 1967 and 73% a year later. Thus, it seems to be an effective late season parasite of alfalfa weevil larvae in Maryland. However, it was not recovered until September in New Jersey in 1967 and then only in the southern 4 fields; in 1968 and 1969, it was found in only 2–3 fields, and parasitism was less than 9%; and in 1970, it was recovered from only 2 fields, and there levels of parasitism were less than 2%.

Adult Parasites

According to Brunson and Coles (1968) the adult parasite *Microctonus aethiopoides* was firmly established by 1968 in about 100 square miles of area in central New Jersey. It was introduced into Maryland in 1965 at Beltsville but was not recovered through 1967 (Blickenstaff et al. 1972). The first record for recovery of *M. aethiopoides* in Maryland was in Frederick County in 1969 (Dysart and Day 1976). *Microctonus colesi,* another parasite of adult alfalfa weevils, was recovered in low numbers from both Maryland and New Jersey by the time of the reported surveys (Drea 1968).

In 1967, *M. colesi* adults were recovered from adult weevils collected in 5 of 10 Maryland fields where *Microctonus* parasitism ranged from 2 to

50%. In New Jersey, in 1967, *Microctonus* spp. parasites were collected from 4 fields, *M. colesi* from 2 (1 of the 6 adults and 1 of the 16 adults collected, respectively), and *M. aethiopoides* from 2 (1 of the 6 adults and 1 of the 8 adults collected, respectively). Also, collections of larvae made in spring of 1968 and held for adult eclosion showed *M. colesi* present in 3 of 10 New Jersey fields with 16.7% parasitized in field 10, 33.3% in field 7, and 66.7% in field 6. One *Microctonus* sp. emerged from 10 adults collected in field 3. In Maryland, collection of adults in the spring of 1968 showed *Microctonus* parasitism in 9 of 10 fields, always at rates less than 5.95%. However, when overwintering adult alfalfa weevils collected in Maryland fields during the winter of 1968–69 were dissected to determine percent parasitism by *Microctonus* spp., 5 of 10 fields contained parasitized adults, and parasitism ranged from 18 to 66%. Also, 1, 3 and 3 *Microctonus* immature parasites were recovered from adult weevils collected January 1969 from New Jersey fields 2, 8 and 9, respectively. In addition, *M. colesi* emerged from adult weevils collected April 1969 in 3 fields. Parasitism ranged from 20 to 33%.

In 1969, in Maryland, larvae were collected from fields in the spring and reared to adults. Then 50 of these adults from each collection taken in fields 3–8, and 10 were treated with the synthetic juvenile hormone to recover *M. colesi*. All living adults were then dissected 30 days after treatment to determine whether any more parasites were present in the host. *M. colesi* emerged from alfalfa weevil adults collected from 6 of the 7 fields and parasitism ranged from 2 to 22% (including the 3 recovered by dissection); the mean was 9.4%.

Microctonus aethiopoides emerged from adults collected in 1969 from Maryland fields 6, 8 and 9. No parasites emerged from adults collected in fields 1–5, and 10. The highest level of parasitism was 19.2% in field 6. In 1970, collections made in the 10 Maryland survey fields in spring showed *M. colesi* present in 8 fields and parasitism ranged from 12.5% in field 3 to 89.3% in field 4. Parasites were not recovered from alfalfa weevil adults collected in fields 7 and 10.

In New Jersey, alfalfa weevil adults were reared from larvae collected in spring 1969. These weevils were held for recovery of parasites until August 19, 1969. On this date 50 adults from fields 3–8, and 10 were each treated with 100 μg of the same synthetic hormone used previously. As a result, *M. colesi* emerged from 2 to 16% of the adults collected from the 7 fields.

Summary and Conclusions

1. Adult alfalfa weevil population levels in New Jersey and Maryland declined steadily from 1967 until spring 1969, but collections from Maryland fields in fall 1969 showed a slight increase over the previous year. This

increase was not reflected by an increase of larvae the following spring. Adult population levels in New Jersey remained about ⅓ to ½ lower than population levels in Maryland.

2. Populations of alfalfa weevil larvae declined from a peak of nearly 1,000/ft² in 1967 to the lowest level recorded, less than 100/ft², in 1970. Despite this near 10-fold decline, there were isolated areas reporting serious damage. Larval populations in New Jersey for the 4 year period remained about ½ to ⅓ lower than larval populations in Maryland.
3. Previous to 1968, Maryland and New Jersey alfalfa fields had shown a characteristic decline in adult weevils from fall to spring of approximately 66%; however, the decline was not evident from 1968 to 1970. This change in behavior of the adult weevil was reflected in the lack of correlation between overwintering adults and peak larval populations for the three seasons, 1968–70. Nevertheless, correlations were obtained between spring adult populations and the subsequent peak larval populations for the period 1966–69, except for the March 1967 collections in Maryland. The conclusion of Blickenstaff et al. (1972) that the number of adults per given time is helpful in predicting potential larval populations is therefore supported.
4. *Bathyplectes curculionis* was the predominant parasite of the alfalfa weevils collected in all 10 Maryland and New Jersey alfalfa fields in 1967–70. The increased synchronization of peak populations of *B. curculionis* and the peak population of larvae in Maryland and New Jersey suggests an increased effectiveness of the parasite during that period, especially in New Jersey. The high levels of parasitism, from 64% in Maryland to 61% in New Jersey, and this increased synchronization made this a very effective parasite.
5. *Bathyplectes anurus* was recovered in 1970, the first recovery in these surveys, from one of the 10 alfalfa fields in New Jersey.
6. Parasitization by *T. incertus* built up very rapidly in Maryland fields from a low of 14% parasitism in 1967 to a high of 73% a year later. The parasite appears late in the season, generally after the first cutting and at a time of low host density. *T. incertus* give indications of being an effective late season parasite of alfalfa weevil larvae in Maryland. However, in New Jersey, *T. incertus* practically disappeared in 1968–70. The low parasitism levels may be a result of the much lower host density in New Jersey alfalfa fields.
7. *Microctonus colesi* and *M. aethiopoides*, parasites of adult alfalfa weevils, were difficult to recover because of the diapause of the host and the diapause of the parasite larvae in the host. Topical application of synthetic juvenile hormone to adult weevils induced early emergence of *Microctonus* parasites. Species identification was a problem if adult *Microctonus* did not emerge. However, based on the available data, both species are

established and increasing in the survey areas of Maryland and New Jersey.

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